A directional active loop receiving antenna system

by J. A. LAMBERT, G3FNZ*

LOOP ANTENNAS have been used for receiving mf and hf signals for many years, and active systems (ie systems in which an electronic amplifier forms an integral part) for not quite as long—but nevertheless for long enough that they are now a recognized tool in the armoury of the radio systems engineer. In the past, loops have been used in portable radios—in the days before ferrites took over as the antenna for the ubiquitous transistor set.

A second use was for direction finding, where the azimuth pattern of a vertically-polarized loop is a figure of eight, thus giving two nulls or minima in received signal strength at 180° to each other (Fig 1). In order to eliminate one of the nulls it was common practice to mount a whip adjacent to the loop and to feed it to one side of the coil that coupled the loop to the tuned rf stage of the receiver. This extra input would unbalance the azimuth pattern to such an extent as to reduce one of the nulls by a significant amount, thus giving a clear definitive directional property to the antenna.

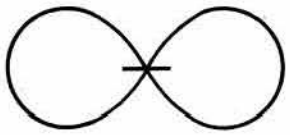

Fig 1. Azimuth pattern of vertically-polarized loop

This unbalancing of the output of a loop can be achieved without the use of a separate whip by converting a single-turn loop into two monopoles by inserting a significant impedance in series with the turn diametrically opposite to the feed point (Fig 2). For magnetically-induced waves the loop will still operate as a continuous loop with the conventional figure of eight azimuth pattern. The two lobes being of opposite electrical polarity (Fig 3).

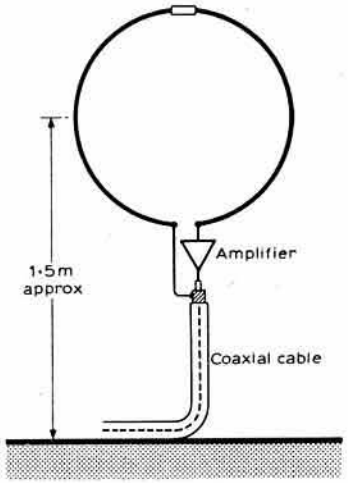

Fig 2. Unbalanced loop achieved by inserting series impedance

If we now consider the performance of the loop with respect to electrically-induced signals, the two halves of the loop perform as short monopoles closely mounted, each of which will produce like polarity outputs (Fig 4). When combined with the magnetically induced outputs these will add in one instance and subtract in the other, thus producing a cardioid pattern (Fig 5).

The choice of load impedance is important, as it will have a marked effect upon the feed point impedance. If a wideband high-performance amplifier is inserted at the feedpoint it is possible to obtain a constant-impedance low-noise output over a wide band of frequencies, eg 2 to 30MHz, and with the very significant capability of being combined into groups to simulate electrically the performance of most hf receiving antenna arrays. An optimum system may therefore be designed for any specific requirement and, if necessary, changes in performance can be easily and rapidly achieved.

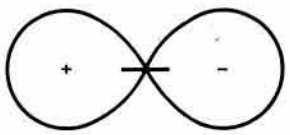

Fig 3. Opposite polarity of the two lobes of the magnetically-induced waves in a continuous loop

Fig 4. Combined like polarity of two close-coupled monopoles

Active loop antennas offer many attractive features, for example:

(a) Simple to install.
(b) Low weight and windloading.
(c) No elaborate structure, concrete foundations etc.
(d) Suitable for permanent, temporary or portable use.
(e) Components immediately reusable in new configurations.
(f) Modules easily stored for emergency operations.
(g) Single flexible cable feeds each loop.
(h) Full control of beamwidths, vertical angle of arrival and null directions.
(i) Loops are normally mounted with their centres about 1·5m above ground—an earthmat system only being needed when low-angle reception is required and is in any case considerably smaller than that required for a conventional antenna.

Loop performance

Typical performance figures obtained with a commercial (as opposed to military) loop are as follows:

Frequency range	2-30MHz
Directivity	3dB
Front-to-back ratio	12dB
Amplifier noise factor	5dB
Intermodulation products. 2nd order	30dBm
3rd order	18dBm
1dB output compression point	0dBm

The dc power supply is normally mounted adjacent to the receiver, and the dc is fed to the loop amplifier via the coaxial cable in order to reduce cabling, with suitable filters fitted to separate the rf from the dc. However, if the distance from the antenna to the psu and receiver is short, then for amateur use it may be better to delete L2/C10 and feed dc in via a separate line.

It will be observed that directivity and not gain is given for the loop—this is because system performance is limited by external noise in the hf

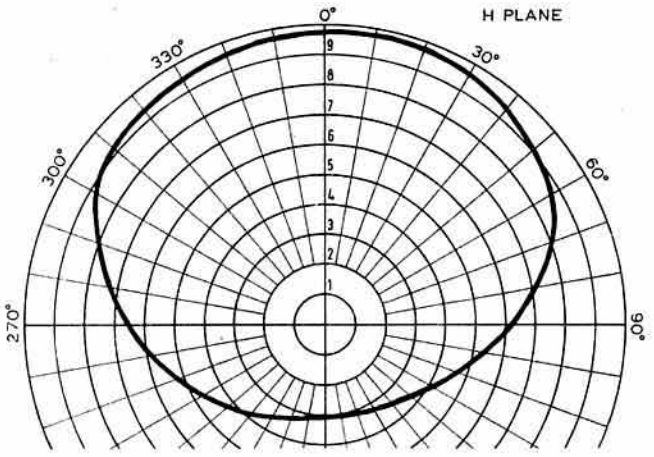

Fig 5. A cardioid horizontal radiation pattern (hrp) is maintained with a consistent front:back ratio—typically 12dB—over a wide band

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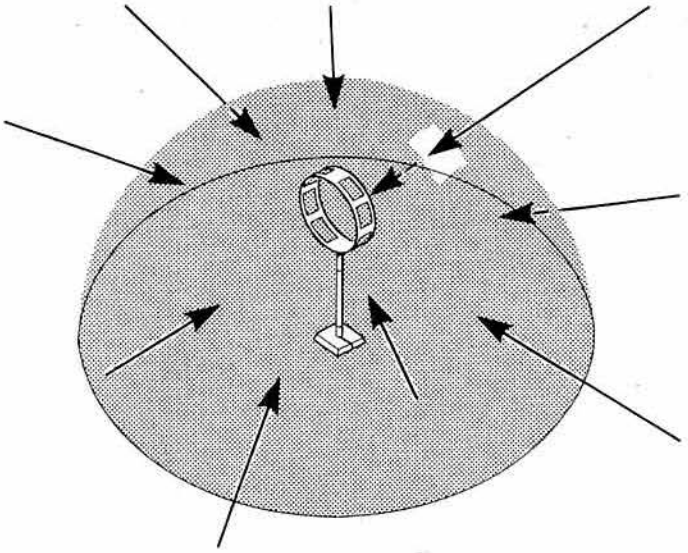


Fig 6. Pictorial representation of arrival of wanted signal and also of unwanted signals, all of which have to be considered when calculating directivity

band. Absolute gain is not the determining factor, as an increase in gain provides more signal but also correspondingly more noise.

Directivity is computed from the radiation pattern of an antenna, and relates the response of an antenna to a plane wave arriving from the optimum direction to the average response to signals arriving from all directions (Fig 6).

Antenna arrays

Normally the power supply unit would be placed in the receiver building, and the dc to the amplifier fed via the coaxial feed, which could be any 50Ω cables such as UR67 for short or medium runs or 0·5in foam-filled cable for long runs.

A simple beam antenna of two or more loops would use a hybrid combining unit fitted on one of the loop mounting poles. This would be connected to the individual loops by cables of equal length in the case of a broadside array, and cables of different lengths to give the required phase relationship for an endfire array.

When more than one beam is required from an array, this is arranged by dividing the outputs from individual loops with suitable phase differences. Splitting and recombining is carried out on the signal output from the power supply unit to avoid the complexity of filtering and recombining the dc supply.

As coaxial cables are used to provide path delays for beam forming, directions of fire are maintained over wide bandwidths. Varying elevation angles of endfire arrays and varying slew-angles for broadside arrays may be obtained sequentially by switching or simultaneously using hybrids.

Endfire (Fig 7)

An endfire array provides a single directional beam with low sidelobe levels and a high back-to-front ratio maintained over a wide frequency band. The radiation patterns, Fig 8, show that as the operating frequency increases, both horizontal and vertical beamwidths decrease. By choosing the correct

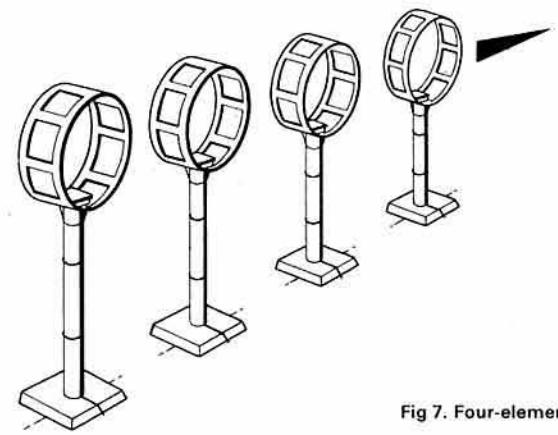


Fig 7. Four-element endfire array

Table 1. Directivity of loop arrays

Frequency	Number of loops	Directivity (dB) Endfire	Broadside
f Max	2	8·1	9·1
$\frac{f\ Max}{2}$	2	5·4	6·2
$\frac{f\ Max}{4}$	2	4·6	4·3
$\frac{f\ Max}{8}$	2	3·9	4·0
$\frac{f\ Max}{16}$	2	3·8	3·9
f Max	4	10·9	12·2
$\frac{f\ Max}{2}$	4	8·1	9·2
$\frac{f\ Max}{4}$	4	5·8	6·3
$\frac{f\ Max}{8}$	4	4·4	4·5
$\frac{f\ Max}{16}$	4	4·1	4·0
f Max	8	13·5	15·9
$\frac{f\ Max}{2}$	8	10·9	12·2
$\frac{f\ Max}{4}$	8	8·1	9·3
$\frac{f\ Max}{8}$	8	5·8	6·3
$\frac{f\ Max}{16}$	8	4·4	4·5

spacing, the performance of an array can be optimized for the frequency band required; see Table 1.

Endfire arrays allow choice of beam elevation angle—from very low angles for long-distance circuits to near-vertical incidence for short circuits. The elevation angle may be fixed or adjustable by switching.

With any of the arrays, unwanted interfering signals can be suppressed by designing nulls into the array pattern. The number or bandwidth of the nulls can be greater for the longer arrays (ie arrays with more loops).

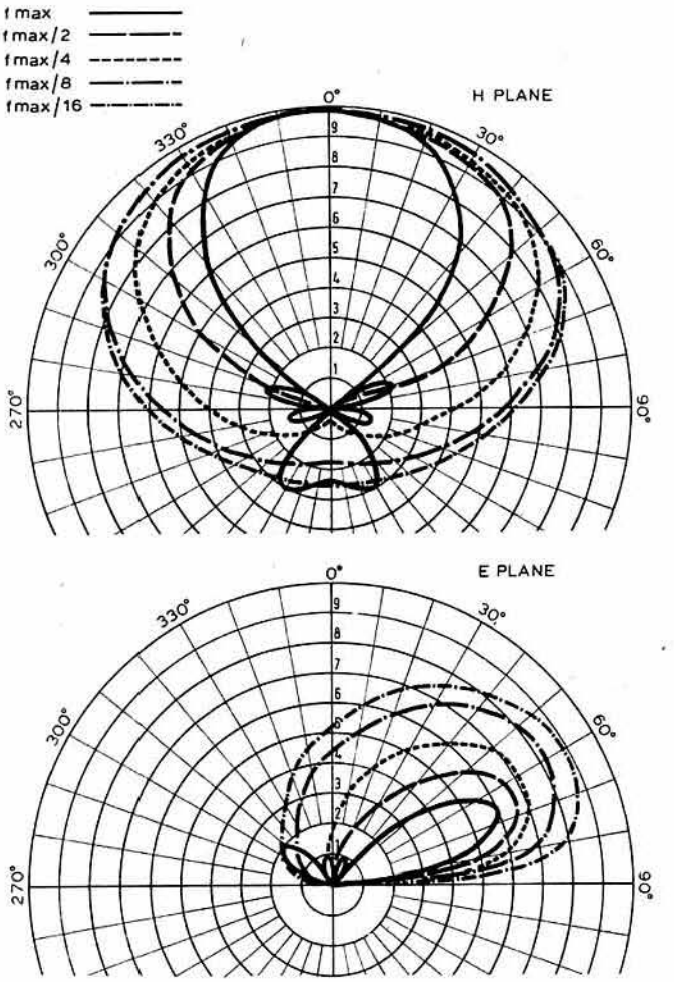


Fig 8. Four loops in endfire is a useful general purpose array which provides an antenna of moderate gain with azimuth and elevation beamwidths which are capable of covering a large area of territory

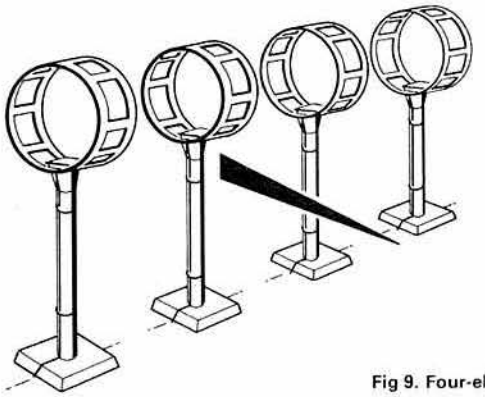


Fig 9. Four-element broadside array

Broadside (Fig 9)

The characteristic of broadside arrays is a beam which is wide in the elevation plane and narrow in the azimuth plane. The vertical radiation pattern is not dependent on the number of elements, and its beamwidth changes little with frequency. The horizontal radiation pattern varies widely with frequency; the beamwidth being inversely proportional to frequency (Fig 10).

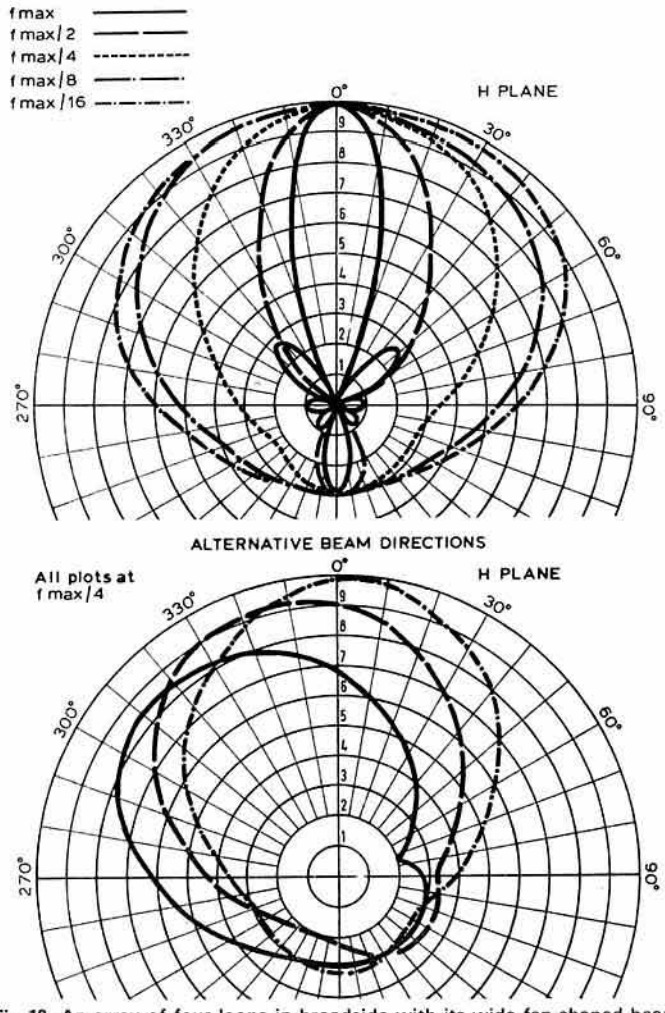
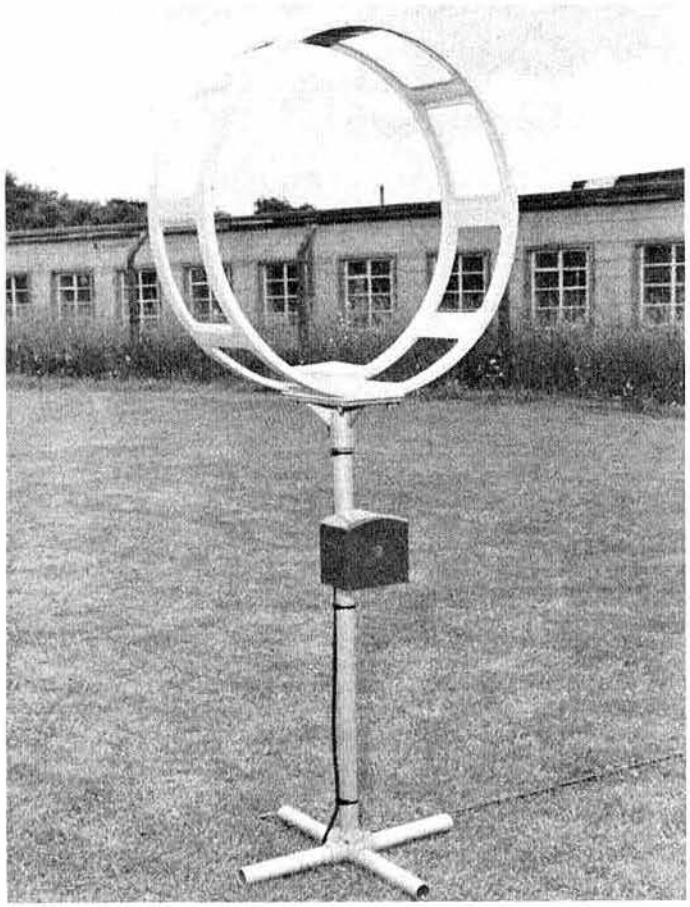


Fig 10. An array of four loops in broadside with its wide fan-shaped beam provides good rejection of unwanted signals. It will accept signals at many angles of arrival, so detailed knowledge of this parameter is not needed

By suitable array design the beam maximum, usually normal to the line of the elements, can be slewed typically up to 45° from the normal. The design can provide a single slewed beam, switched slew angles or a number of simultaneous outputs to different receivers.

Arrangements in which elements are arrayed in two dimensions—ranks and files—can be designed to combine the properties of broadside and endfire arrays.



A single active loop on a temporary stand. The amplifier is contained in the box mounted within the loop. The large box on the support pole is a hybrid combiner unit for a multi-loop array. Notwithstanding its appearance this is a single-turn loop—the apertures being inserted to reduce windloading

Dual beam

It has previously been mentioned that it is possible, in the case of an endfire array, to steer the elevation pattern—and similarly the azimuth pattern—in a broadside array. In systems engineering it is sometimes found to be desirable to have both high and low angles of elevation covered or to receive simultaneous circuits from different azimuth bearings. To meet such requirements it is possible to provide equipment to enable two distinct beams to be received independently from one array.

The design of the individual array is identical to that for covering endfire

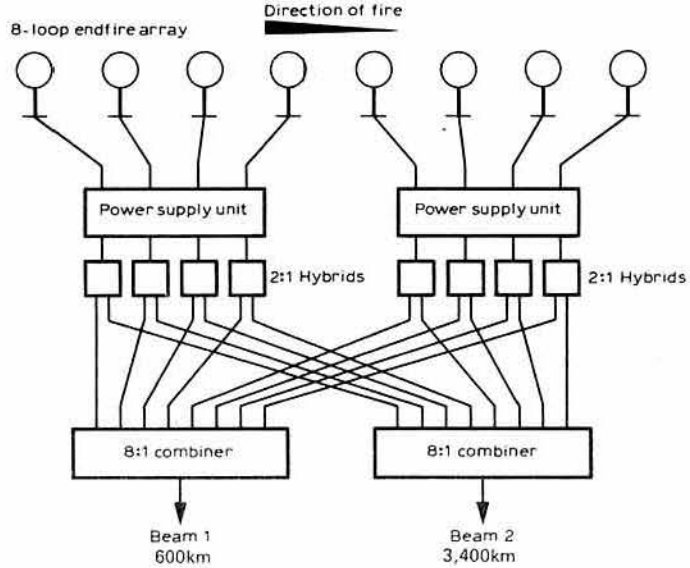


Fig 11. Block diagram of an eight-loop endfire array with dual beams to receive simultaneous signals from two circuits at distances of 600 and 3,400km

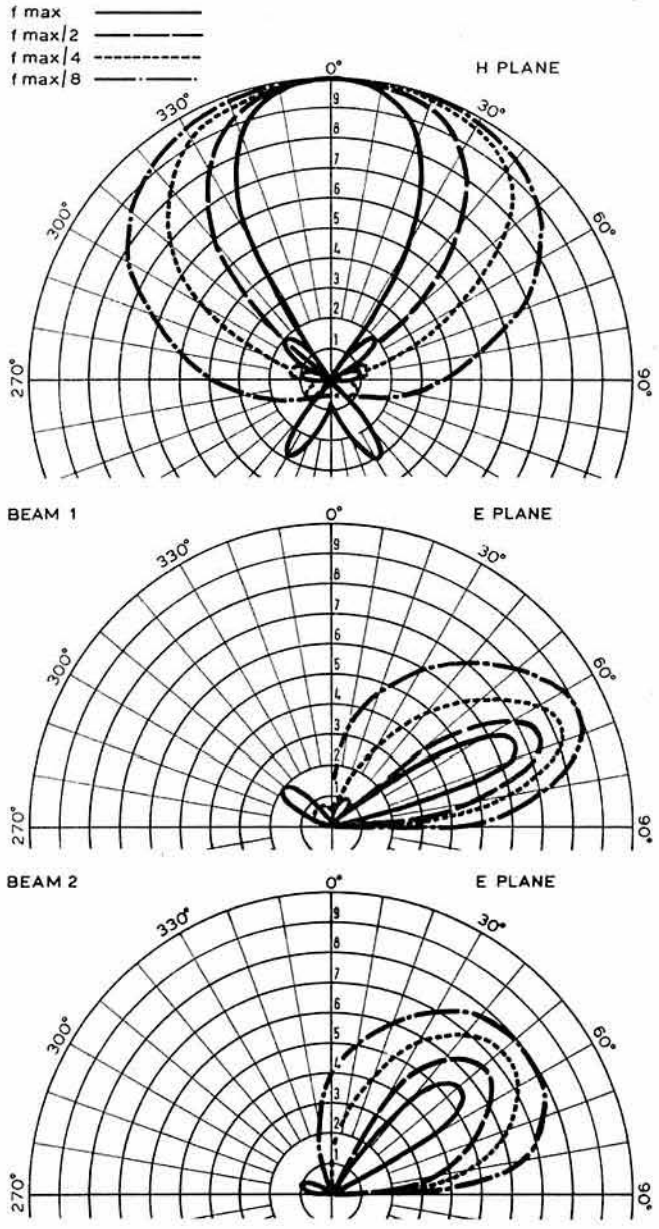


Fig 12. Beam patterns of the eight-loop endfire array with dual beams shown in Fig 11

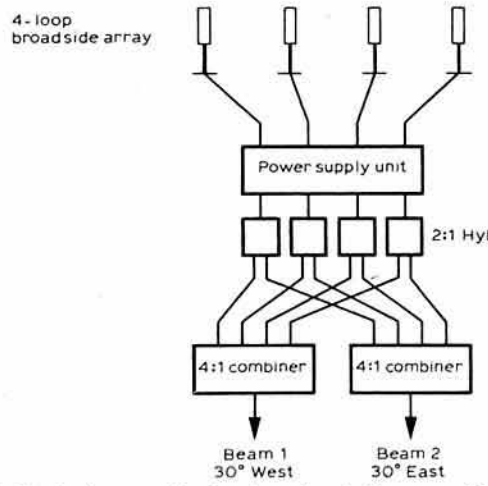


Fig 13. Block diagram of a four-loop broadside array with dual beams to receive two circuits at distances of 800 and 1,200km bearings separated by 60° in azimuth

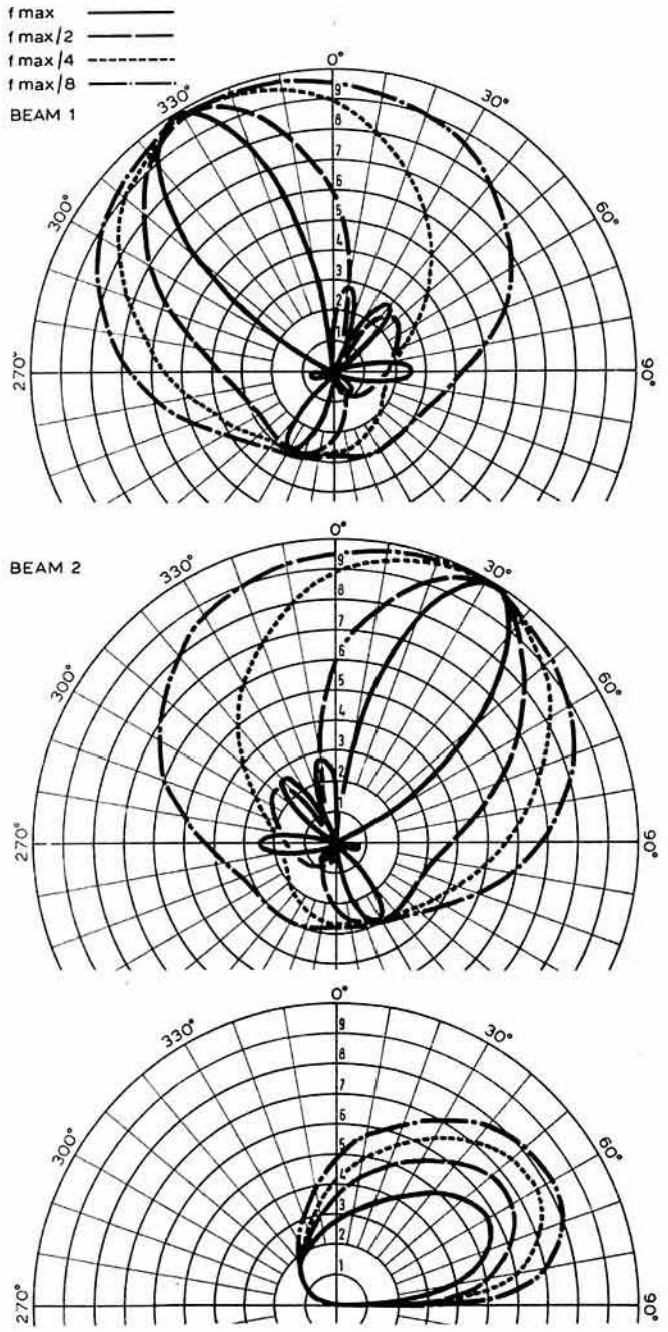


Fig 14. Beam patterns of the four-loop broadside array with dual beams shown in Fig 13

and broadside arrays. It is important to note that the two outputs are completely independent of each other, and it is therefore possible to receive a long distance hf signal using that output of the endfire array providing the low-angle coverage, while at the same time receiving a short-distance signal from the beam steered to cover the higher angles (Figs 11 and 12).

In the broadside application it would be possible to receive a signal from, say, 30° east of the normal bearing and at the same time receive another circuit coming, say, from 30° west from the other output, (Figs 13 and 14). It must be remembered when deciding to use a two-beam array that the array beams must be within the limits of the beam of a single loop, ie it would be unwise to steer a beam in elevation by more than 50° or performance will fall off considerably. In the same way, when steering the broadside array it is necessary to stay within the azimuth beamwidth of a single loop.

A further restraint on beam steering is the appearance of large side lobes when the beam is steered over a wide angle. The appearance of these lobes limits the steering of the beam of high-directivity arrays to around ±3 beamwidths.

It will be noted that for this type of system it is necessary to bring back an individual cable from each of the loops to the receiver room.

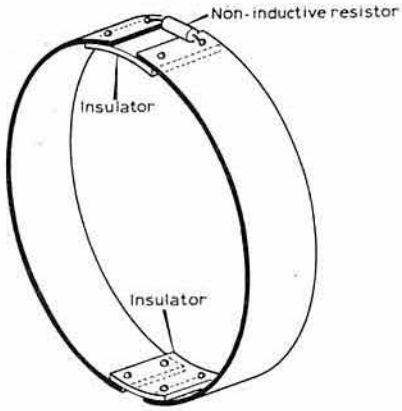
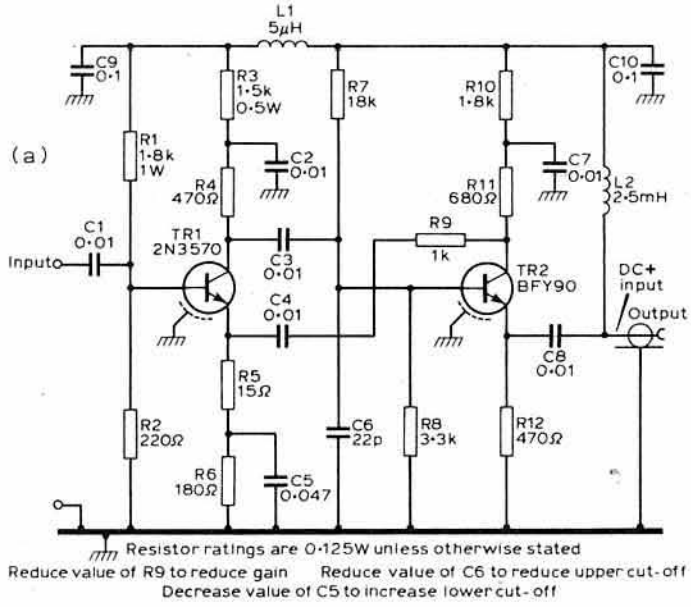


Fig 15. Suggested construction of an experimental loop antenna, the amplifier being connected across the lower insulator

Other configurations

There are many more configurations possible, such as constant-performance arrays of loops in log-periodic form to give a constant-azimuth beamwidth over a wide frequency band, or sector arrays where loops are mounted in a ring and adjacent loop groups switched into use to give azimuth beam selection.

The constant-performance array of loops placed in log-periodic form may also be utilized to form an azimuth sector coverage antenna by placing



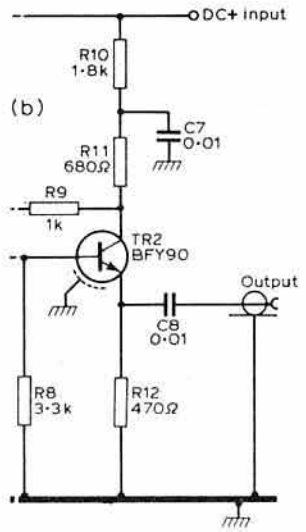


Fig 16. Amplifier circuit diagram: (a) shows the normal arrangement for feeding the dc input via the coaxial cable; (b) shows the alternative arrangement for a separate dc input

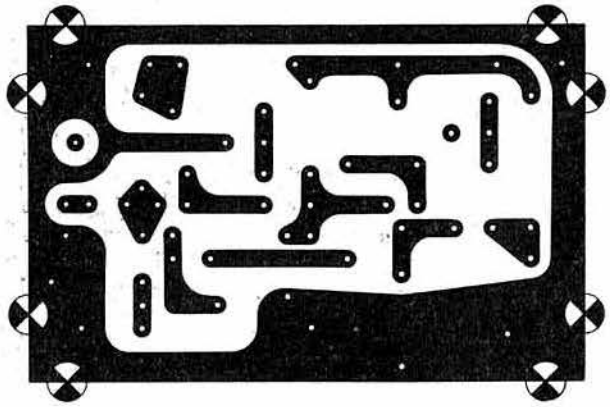


Fig 17. Printed circuit board, Side 1

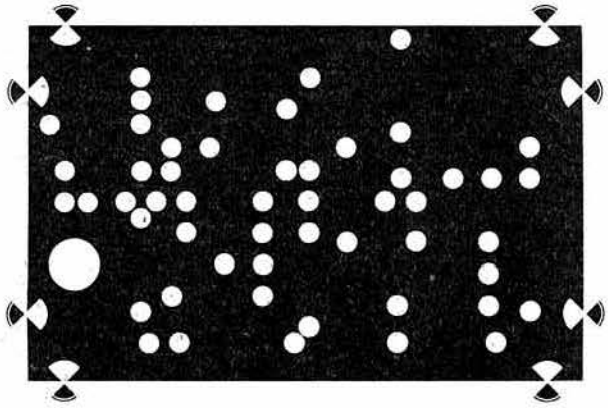


Fig 18. Printed circuit board, Side 2

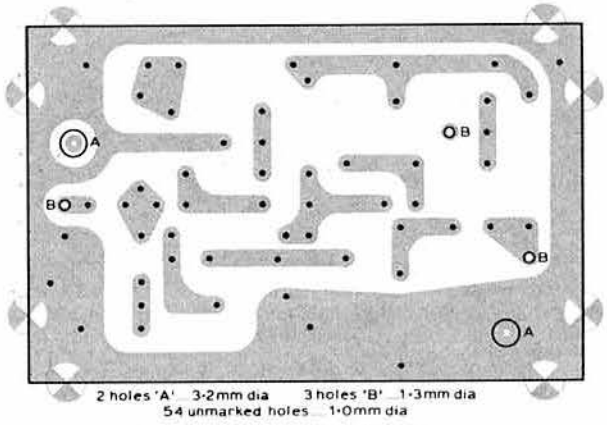


Fig 19. Printed circuit board drilling data

log arrays in the form of a rosette; by combining adjacent arrays a constant beamwidth is achieved in both azimuth and elevation over a wide frequency range of up to 2–30MHz. The composite antenna may be designed to meet the exact requirements of the system engineer.

Construction

The construction of loops for experimental purposes, hf band monitoring, Intruder Watch etc, should present no problems. The loop itself is 1m in diameter and, in order to achieve a substantially constant match to the amplifier together with structural stability, it is suggested that it be made from a 150mm-wide strip of 16swg aluminium. Having formed the loop it should be cut into two equal parts (Fig 15) and then rejoined, utilizing two blocks of insulating material, thus resulting in a firm 360° loop separated into two electrically equal parts.

A 0·5W carbon non-inductive resistor of a value between 47 and 100Ω is then connected across one of the loop junctions, and a broadband low-gain amplifier across the other. The amplifier should be broadband from 2 to 30MHz with low noise and low level of intermodulation products. The design of a suitable amplifier is shown in Figs 16–20, and it will be noted that

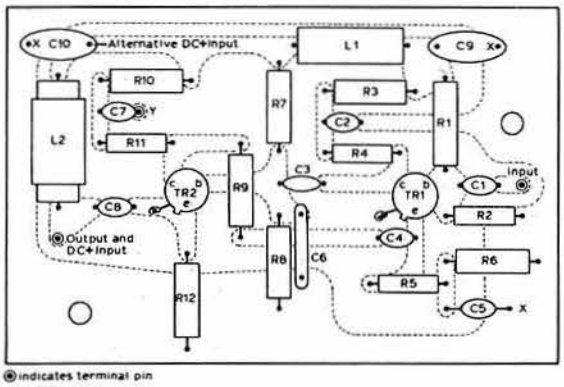


Fig 20. Printed circuit board component layout
1. All components to be spaced approximately 0·06in (1·5mm) from face of board.
2. Earth leads of transistors to be soldered to component side of board as shown.
3. Connections at points marked "X" to be soldered on both sides of board.
4. Pin marked "Y" to be soldered to component side of board

it incorporates a filter to separate the rf from the dc supply. It will be necessary to provide a 24V dc supply capable of providing 30mA, and this unit will also require a filter to enable the rf only to be connected to the station receiver.

It has been stated that optimum performance is obtained when the loop is 1·5m above ground, and although the professional version of the loop utilizes a custom-produced casting, the amateur constructor will find that an electrical conduit flange, plus 1·5m of conduit to be a satisfactory method of mounting.

An interesting series of experiments may comprise varying the loop height and altering the value of the element-joining resistor.

Components list

R1	1·8k 1W RS	**C1, 2, 3, 4, 7, 8**	0·01μF min ceramic plate 40V dc Sasco
R2	220 0·125W RS		
R3	1·5k 0·5W RS		
R4, 12	470 0·125W RS	**C5**	0·47μF silvered mica RS
R5	15 0·125W RS		
R6	180 0·125W RS	**C6**	22pF silvered mica RS
R7	18k 0·125W RS	**C9, 10**	0·1μF mico-min plaquette RS
R8	3·3k 0·125W RS		
R9	1k 0·125W RS	**L1**	5μH 1A RS238-255 or equiv
R10	1·8k 0·125W RS		
R11	680 0·125W RS	**L2**	2·5μH Home Radio
		TR1	2N3570 Fairchild Micro Marketing
Terminal pins	Type SS 3-off RS		
		TR2	BFY90 Farnell
		PCB	FR4GID double-sided 1·5 by 46 by 72·6mm

Acknowledgement

The author expresses his appreciation to the management of C & S Antennas Ltd for permission to publish data and the photograph contained in this article. □

BOOK REVIEWS

Radio Handbook (22nd edn). Edited by William I. Orr, W6SAI. Published by Howard W. Sams & Co Inc (UK Prentice/Hall International). 1,200 large double-column pages. Price £24.45.

In *Rad Com* June 1980, in reviewing the 1,135-page 21st edition of this mammoth, long-established and deservedly popular amateur radio handbook, I highlighted its excellent value, just over 1·1p/page for a well-printed, hard-cover book. Sadly, but perhaps not surprisingly, the new edition has almost doubled in price and now costs approximately 2p/page, though this must be rated as still good value for money by current standards. The new edition has 64 more pages and about double this number of fresh material, with useful up-dating noted in many, though by no means all, of the 35 chapters, and roughly 90 per cent of the material is carried forward from earlier editions. This does not mean that the book is badly dated, but it does mean that one cannot recommend it as a "good buy" for those whose shelves already include a recent edition.

The new edition is particularly strong on high-power linears ranging up to a 4kW p.e.p. amplifier (8877 power triode with 4kV 1A power supply) designated "for commercial service". It is perhaps just as well that "danger high voltage" warnings have been added to many of the valve amplifier diagrams! The chapter on frequency synthesis has been almost doubled in length, and rather more material has been included on uhf—including a 600W amplifier (3CX400U7) for the proposed American 902 to 928MHz band, and there is even an explanation of multi-cavity klystrons for high-power shf operation. Although information is included on the WARC 1979 bands, very few of the constructional projects (and none of the hf receivers) make provision for them—indeed the receivers and exciters chapter remains virtually untouched. Several new antenna ideas have been added, including a number originally published in *Rad Com*. Re-arrangement of a number of the chapters improves the general presentation, and indeed for his many skilful revisions of this enormous and comprehensive handbook Bill Orr deserves the thanks of all amateurs interested in the theory and construction of their equipment. An historical sidenote: the publishers have dropped the old "Editors and Engineers" imprint although for many years this had been maintained only as a division of the Howard W. Sams publishing house.

Chapters: Introduction to amateur radio communication (17pp) Direct-current circuits (25pp). Alternating current, impedance and resonant circuits (37pp). Semiconductor devices (54pp). Electron tubes (11pp). Special microwave tubes (13pp). Radio-frequency power amplifiers (26pp). Specialized circuitry for semiconductors and vacuum tubes (13pp). Single-sideband transmission and reception (32pp). Communication receiver fundamentals (51pp). Generation and amplification of radio-frequency energy (66pp). Frequency-synthesis (23pp). Frequency modulation and repeaters (27pp). Specialized amateur communications systems and techniques (42pp). Amplitude modulation and audio processing (19pp). Radio interference—rfi (23pp). Equipment design (25pp). Transmitter keying and control (17pp). Mobile and portable equipment (54pp). Receivers and exciters (73pp). HF and vhf power amplifier design (22pp). HF and vhf power amplifier construction (136pp). Power supplies (44pp). Radiation and propagation (31pp). The transmission line (18pp). Antenna matching systems (20pp). HF general purpose antennas (28pp). HF fixed directive antennas (20pp). VHF and uhf antennas (36pp). Electronic test equipment (44pp). The oscilloscope (18pp). Construction practices (14pp). Electronic maintenance and calculations (50pp). Nomenclature of components and miscellaneous data (14pp). Index (8pp).

G3VA

The Gunnplexer Cookbook, R. M. Richardson, W4UCH. Published by The Ham Radio Publishing Group. Obtainable from M/A Com Ltd, Humphries Road, Dunstable, Beds LU5 4SX. Price £11.

Given the worldwide popularity of the versatile 10GHz Gunnplexer manufactured by Microwave Associates, it was inevitable that sooner or later literature describing its application in the field of amateur radio would appear. W4UCH in Vol 1 of the *Gunnplexer Cookbook* has attempted to do this with somewhat mixed results. Although the book has only recently been published, in places the text is very dated, eg it refers to the 1976 10GHz dx record as being current.

The section in Chapter 1 dealing with Gunn diode theory is very superficial. The *Ham Radio* article by Fisk should have been included as it would have not only set the scene for later chapters but would also help the reader to understand the limitations of the Gunnplexer for narrow-band applications. Also, of course, the concept of negative resistance and how it can be made to occur at 10GHz should be of interest to the reader. (Personally it is felt that the microwave amateur likes to know how the devices that he uses actually work!)

Chapter 2 contains some useful information on Gunnplexer system path capabilities and oscillator characterization. There is no discussion, however, of the threshold performance of the various types of modulation which might be used with the Gunnplexer. This is a pity because for many amateurs the weak signal or marginal path performance of a microwave system is of great interest.

The following two chapters deal with power supplies and proportional temperature control systems. The latter are obviously meant for use in home stations, due to the heavy current drain incurred. In practice it is questionable whether such a system is really necessary provided that an efficient afc system is employed.

The next chapter deals with i.f. amplifiers, and includes very useful information on suitable preamplifiers. A design for a home-brew anf motor would have been useful here to back up comments on the importance of correct matching between the preamplifier and the mixer diode.

Chapter 7, which deals with weatherproofing and mounting the Gunnplexer head, would have been much more useful if it had included a design for a rugged, dismountable tripod. The use of a photographic tripod, as depicted in the illustrations, is definitely not to be recommended!

The next three chapters cover afc systems, a basic complete 10GHz transceiver and a weak signal source. To the reviewer, the latter seemed unnecessarily complex, the design by G3WDG being much preferred due to its much smaller parts count.

The remaining chapters of the book are devoted to descriptions of a narrow-band phase-locked Gunnplexer system and wide-band links for tv and computer applications. Although the text on the "Crystalmatic" narrow-band system makes interesting reading, the reviewer feels that the G3JVL ssb system is much easier to implement, albeit with lower resulting output power.

Although the above comments may appear unduly critical it is hoped that they are taken as being constructive and will be noted in the preparation of any future revised edition. The reviewer found the *Cookbook* made very interesting and informative reading, and hopes that Volume 2 will not be too long in arriving!

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